Application of vertical electrical sounding method to identify distribution of hot groundwater around the hotsprings in geothermal prospect area

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SUMMARY

Field survey with geoelectric method has been conducted in the Songgoriti geothermal prospect area, Malang, Indonesia. This area is located between Mount Arjuno and Mount Welirang. The aim of this study is to identify the distribution of hot groundwater. Subsurface resistivity data acquisition is done by using Vertical Electrical Sounding (VES) in the four sounding points around the hotsprings with a maximum path length of 160 meters. Data from this measurement is the apparent resistivity that be a response model of the subsurface rock model parameters at each depth. The true resistivity of the subsurface model parameters is determined by inversion modeling. Result of data processing generates a resistivity model of each layer of rock at depth. This study successfully estimate the hot groundwater aquifer layer in the study area. The layer of hot groundwater aquifer is identified by low resistivity in the VES-1 point, VES-2 point and VES-3 point with different depth and thickness. Resistivity of hot groundwater layer is about 19.5-43.1 ohmmeter with the largest thickness in VES-3 point with the direction of orientation from Mount Welirang to southeast.

Key words: VES, resistivity, hot groundwater, hotsprings, geothermal.

INTRODUCTION

Based on the law of the Republic of Indonesia Number 27 Years 2003 stated that geothermal energy or often called geothermal is a source of heat energy contained in the hot water, steam, and rock along with the associated minerals and other gases that are genetically inherent in a geothermal system. Indonesia is a country that has the largest geothermal potential in the world with reserves of approximately 40% of the world's geothermal energy reserves. In accordance with the Presidential Regulation Number 5 Year 2006 concerning National Energy Policy that the utilization of geothermal energy is targeted to be the optimal primary energy more than 5% in 2025. Therefore, the geothermal exploration activities has been increasing rapidly for the last ten years with various geophysical methods in order to support the acceleration process of increasing the national energy capacity.

In general, the essential constituent elements of a geothermal system consist of the source of heat, the permeable reservoir rock and the fluid that carries heat flow (Goff and Cathy, 2000). The heat source is driven by the heat generated from the intrusion of igneous rocks. Reservoir rock is a rock where fluid accumulates. The fluid in the geothermal system can be either hot water or steam. The sign of potential area constructed with geothermal energy can be shown by the manifestation on the surface such as hot spring.

Almost all geophysical methods can be used for geothermal exploration. But the common technique used are the method of electrical and thermal methods. Geophysical methods provide an effective addition data information of subsurface condition which consume cost relative lower than drilling which often spend a very high cost (Gylfi and Axel, 1991). Hot water aquifers in geothermal system can be identified as an area with low resistivity anomaly caused by the water characteristic which is good conductor. Resistivity measurements in the vertical direction or called Vertical Electrical Sounding (VES) is one of the geoelectric method for determine the resistivity changes of the subsurface variation with depth (Telford et al, 1990). This study aims to identify the distribution of hot groundwater in geothermal prospect area in Songgoriti region, Malang using inversion method for mapping the subsurface resistivity of VES data.

STUDY AREA

The area of study is located in geothermal prospect of Songgoriti region, Malang, Indonesia. Geothermal manifestation that found is a hotspring. Geographically, the study area is located between Mt. Welirang and Mt.Arjuno. The Investigation and deployment of the flow direction in the area of hotsprings is not known exactly although there are early indications that the flow of water come from Mt. Welirang. Mapping the distribution and direction of the flow of hotsprings is one of the first steps to determine the location of the actual hot groundwater reservoir.

Geologically, the study area composed of volcanic rock units Arjuno-Welirang with rock types are volcanic breccia, lavas, tuffaceous breccias and tuffs (Santosa, 1986). Lava produced by Mt.Arjuno consists of olivine basalt and pyroxene andesite, while the lava from Mount Welirang consists of augite hyperstein andesite (Verbeek and Fennema, 1896). The Elevation of the measurement location about 1500 meters above sea level.

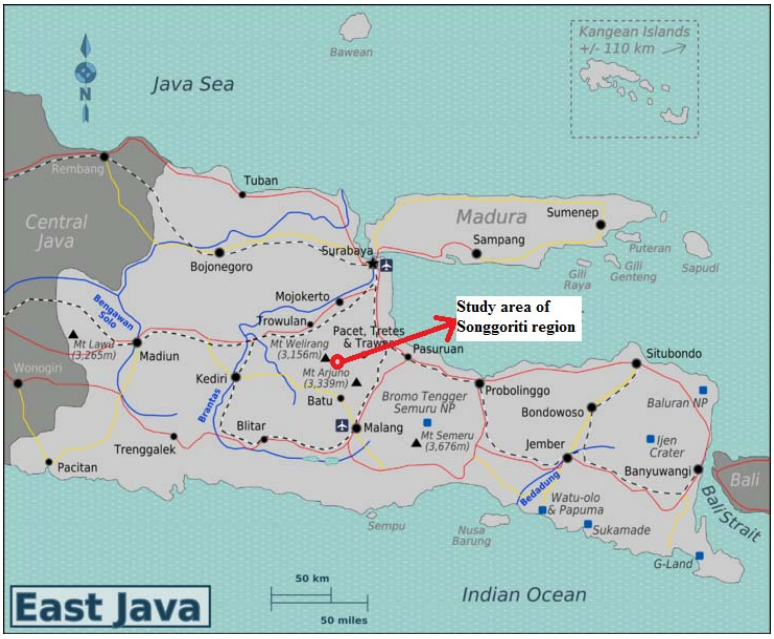

Figure 1. Location map of the Songgoriti region, Malang, Province of East Java, Indonesia

Geothermal prospects in Songgoriti indicated by the presence of hotspring where the temperature is around 47°C. Songgoriti system is different with Mt. Welirang in northern part due to the different characteristics of the fluid in the area. Heat source is allegedly derived from Mt. Panderman or Mt. Kawi where both the mountain are split off from a large eruption of Mt. Arjuno-Welirang in the past. Geothermometer indicates the temperature of reservoir in this area about 170-210°C. Active surface geothermal manifestations in Songgoriti only indicate a geothermal system in outflow zone controlled by the structure and lithologic contacts of the area. The potential in this area is 25 MW (Utama et al, 2012).

METHOD

The data acquisition in the field is conducted using Schlumberger array. The surveys are taken at four sounding points around the hotsprings with a maximum path length of 160 meters. Figure 2 shows the positions of the four sounding points namely VES-1, VES-2, VES-3 dan VES-4. The measurements are carried out by injecting two current electrodes in the surface and measuring the voltage difference by two potential electrodes. The calculation is performed to obtain the apparent resistivity values of the measured data. These values will change when change the location and separation distance of the electrodes. Apparent resistivity can be calculated by dividing the voltage by the injected current then multiplying by a configuration factor.

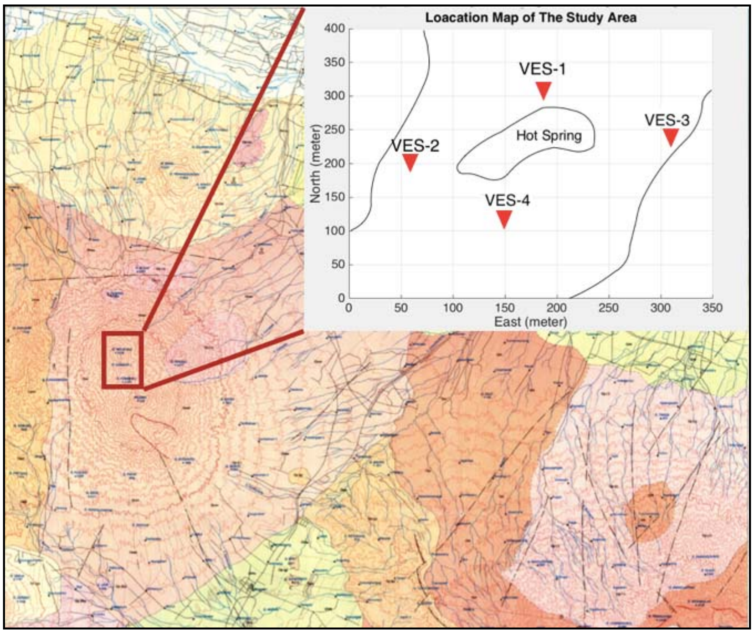

Figure 2. Location of vertical electrical sounding measurement in the geological map of study area

Data processing was performed using inverse modeling. True resistivity values of the subsurface model is determined by curve matching with the curve of apparent resistivity values (Bobachev et al, 2001). The basic principle of processing is to use a linear least squares inversion with early model iteratively modified to obtain a response model that fits the observed data. In this case, the apparent resistivity is a model response while the true resistivity, thickness and depth below the surface layer are 1D model parameters to be determined.

Data interpretation is performed to estimate subsurface lithology and rock layers that are identified as the layer of hot groundwater aquifers. The resistivity of rocks, minerals, soil and chemical elements in general have been obtained through a variety of measurements that have been done can be used as a reference for the process of conversion of the value of the resistivity to lithologic layers of rock containing water (Telford et al, 1990, Reynolds, 1987, Ward and Stanley, 1990). This interpretation is also based on the condition of lithology or rock types in the study area.

RESULTS

The data processing stage generates a 1D resistivity model of the subsurface of each sounding points Figure 3 shows one example of the result of data processing which is the result of data processing at VES-2 point. Figure 3a shows the matching between the apparent resistivity values of the measurement results with the model curve of the calculation. The x-axis is log of AB/2 (a half of the current electrode distance) in meters and the y-axis is the apparent resistivity in ohmmeter. Figure 3b shows the 1D resistivity models with the x-axis is log of true resistivity in ohmmeter and the y-axis is the layer depth in meters.

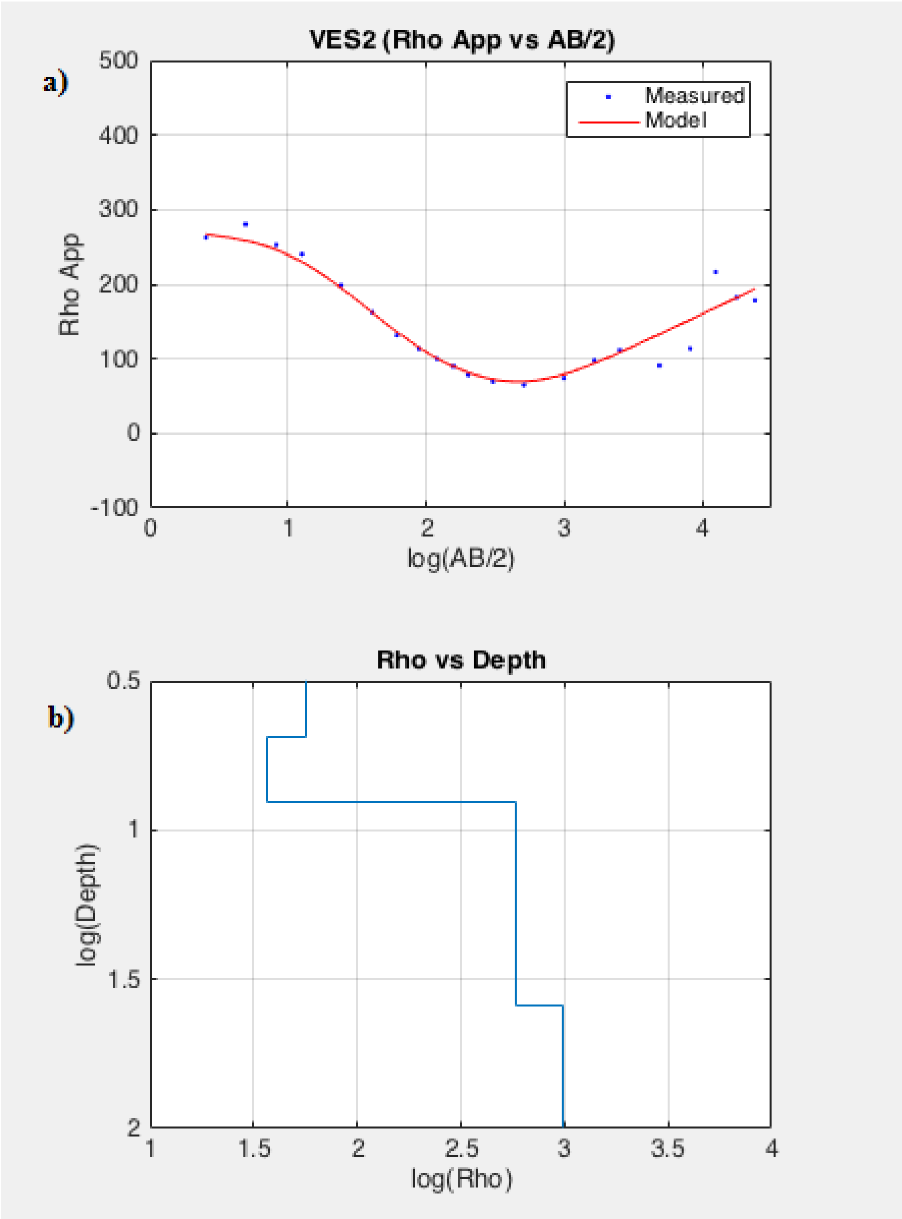

Figure 3. Representative of inverse modelling result: (a) curve fitting (b) 1D resistivity model

Error of modeling results at every point of sounding is less than 10%. This indicates a great match between the measured data with the model of calculation result (inversion). 1D resistivity model of every point of the sounding points consists of four layers with various thickness and resistivity. The maximum depth can be achieved from the modeling reaches 55 meters.

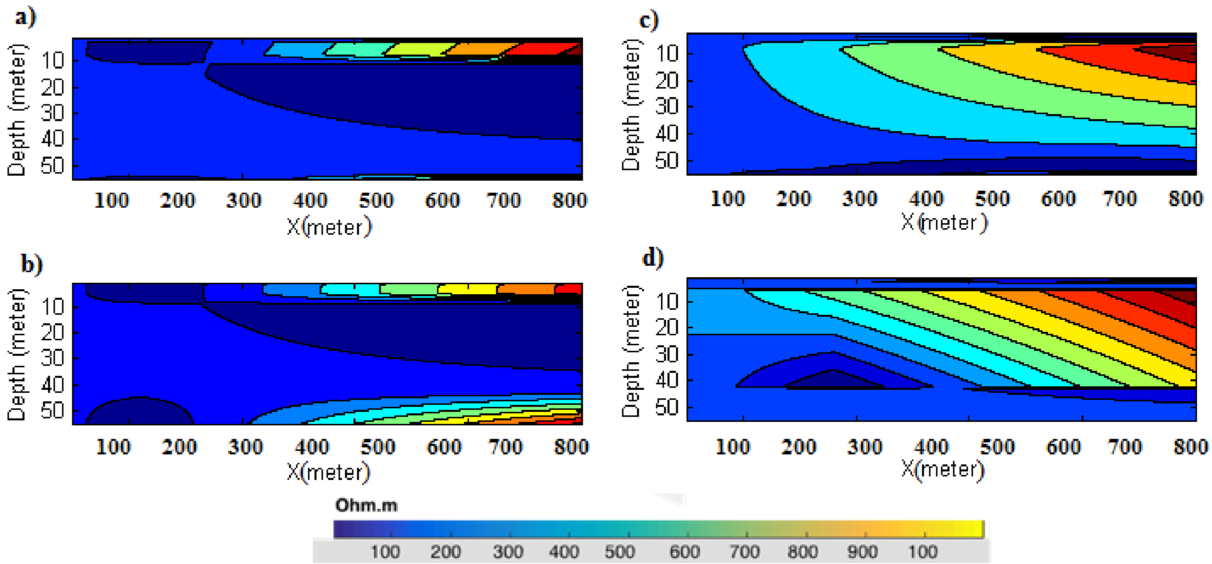

Figure 4. Resistivity interpolation of: (a) VES-1, VES-2 (b) VES-1, VES-3 (c) VES-2,VES-4 (d) VES-3, VES-4

The distance between each sounding points is quite short that allowed for doing a linear interpolation to get the 2-D visualization for every two couple point start from (VES-1, VES-2), (VES-1, VES-3), (VES-2, VES-4) and (VES-3, VES-4) are shown in Figure 4. Cube display of data interpolation are shown in Figure 5. In VES-1 point, low resistivity is about 39.4 ohmmeter at a depth of 42-53 meters. In VES-2 point, low resistivity is about 36.9-56.6 ohmmeter at a depth of 8-15 meters. Meanwhile in VES-4 point, low resistivity is about 19.5-43.1 ohmmeter at a depth of 2-50 meters. Distribution of hot groundwater comes from Mt. Welirang with orientation direction from northwest to southeast.

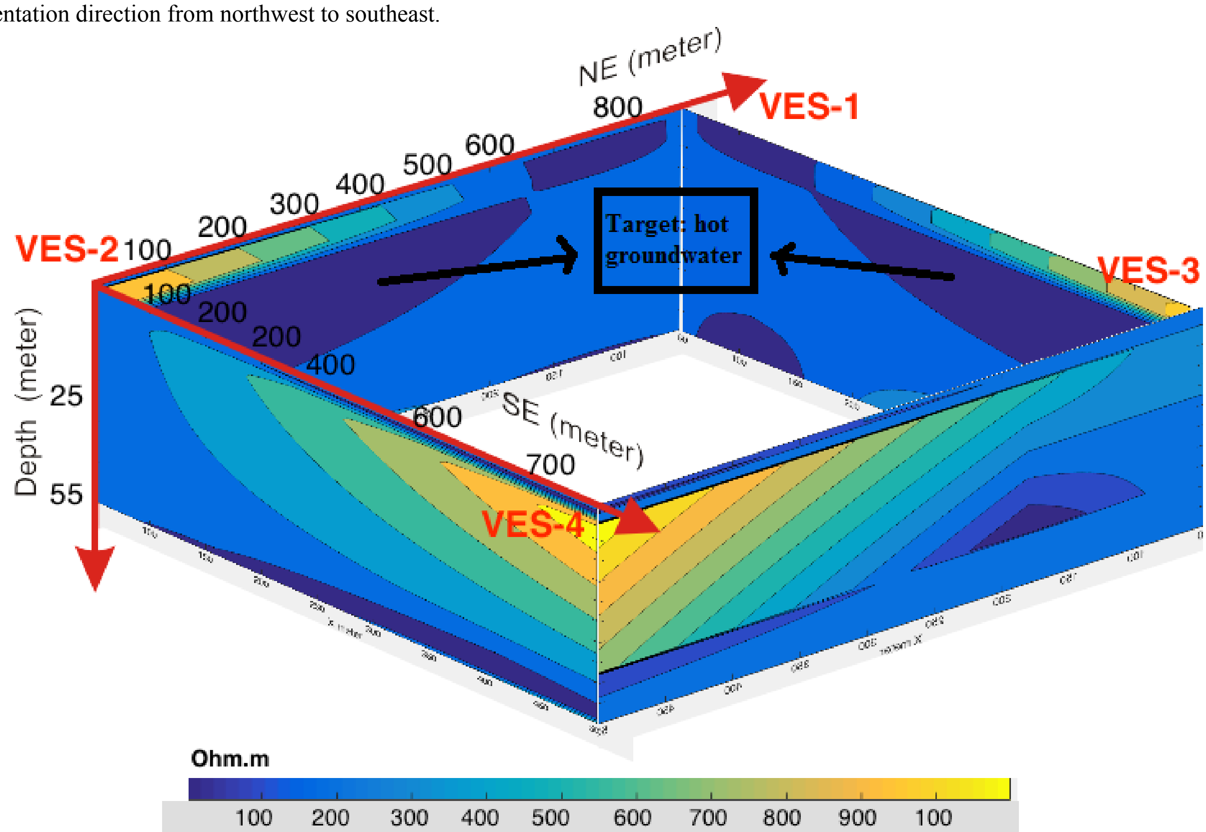

Figure 5. 2D visualization of the data interpolation

CONCLUSIONS

Inversion of VES data can model the subsurface resistivity values and identify the distribution of hot groundwater in the study area. A layer of hot groundwater distribution is identified by low resistivity in the VES-1 point, VES-2 point and VES-3 point with different depth and thickness. Resistivity of hot groundwater layer is about 19-43 ohmmeter with the largest thickness about 48 meters in VES-3 point with the direction of orientation from northwest to southeast.

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REFERENCES

Bobachev, A. B., I. N. Modin, and V. A. Shevnin. 2001. IPI2Win Software - a Program for ID Automatic and Manual Interpretation of VES-Curves: Moscow State Univ., Fac. Geol., Geophysics Dept.

Goff, F. and Cathy, J. 2000. Encyclopedia of Volcanoes: Geotermal System. University of Rhode Island, USA.

Gylfi, P. H. and Axel, B. 1991. Geophysical Exploration For Geothemal Resources Principles and Application. UNU Geothermal Training Programme Reykjavik, Iceland

Reynolds, J.M. 1987. The Role of Surface Geophysics in the Assessment of Regional Groundwater Potential in Northern Nigeria in Planning and Engineering Geology. Geological Society Engineering Group Special Publication No. 4, 185-190.

Santosa, S., and Suwarti. 1992. Geological Map of the Malang Quadrangle Jawa. Geological Research and Development Centre. Bandung, Indonesia

Telford, W. M., Geldart, L. P. and Sheriff, R. E. 1990. Applied Geophysics, Second Edition. Cambridge University Press, United State of America.

Utama, Andika P., Ariya Dwinanto, Johnnedy Situmorang, Mulkanul Hikmi, Robi Irshamukti. 2012. Green Field Geothermal Systems In Java, Indonesia. Bandung. 1st ITB Geothermal Workshop.

Ward, Stanley H., 1990, "Resistivity and Induced Polarization Method. In Geotechniacal and Environmental Geophysics, Volume 1: Review and Tutorial", Society of Exploration Geophysics Investigation in Geophysics, 147-189FLEXChip Signal Processor (MC68175/D)